TECHNICAL REPORT
FD-25

A COMPARISON OF TENDERNESS PARAMETERS IN DEHYDRATED MEAT

by

Fred A. Andrews and Chester E. Underwood

BJORKSTEN RESEARCH LABORATORIES, Inc.
Madison, Wisconsin

Contract No. DA 19-129-AMC-2102(N)

September 1965

U. S. Army Materiel Command
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

AD

TECHNICAL REPORT
FD-25

A COMPARISON OF TENDERNESS PARAMETERS IN DEHYDRATED MEAT

by

Fred A. Andrews and Chester E. Underwood

Bjorksten Research Laboratories, Inc.
Madison, Wisconsin

Contract No. DA19-129-AMC-2102(N)

Project Reference:
7X84-06-033

September 1965

U. S. Army Materiel Command
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01762

FOREWORD

The tenderness of meat items prepared from dehydrated material is determined largely by the quality and treatment of the meat before dehydration. To insure that dehydrated meat intended for military feeding is of requisite high quality, methods for selecting starting materials and for controlling processing are required. No such tests for tenderness currently exist.

The work covered in this report, performed by Bjorksten Research Laboratories, Inc. under Contract No. DA19-129-AMC-2102(N) (September 1962 - September 1963) represents a comparison of two mechanical methods for measuring tenderness of both raw and cooked beef with panel scores of tenderness on the cooked samples. An attempt to relate differences in tenderness to differences in composition and in mineral content is also reported. The investigator was Fred A. Andrews. His collaborator was Chester E. Underwood.

The U. S. Army Natick Laboratories Project Officer was John G. Kapsalis, and the Alternate Project Officer was Albert S. Henick both of Food Chemistry Branch, Food Division.

FERDINAND P. MEHRLICH, Ph.D.
Director
Food Division

APPROVED:

DALE H. SIELING, Ph.D.
Scientific Director

W. W. Vaughan
Brigadier General, USA
Commanding

CONTENTS

ABSTRACT

Longissimus dorsi muscles from 32 beef carcasses were analyzed for tenderness using the Warner-Bratzler shear test, a new rotating knife tenderometer, and an organoleptic panel. In addition, 18 minerals, adenosine triphosphate, and proximate analyses were made.

The rotating knife tenderometer and the Warner-Bratzler shear test were found to correlate well with the sensory panel (r=+0.57, -0.66).

Iron content of the tissues was also found to correlate with the sensory panel (r=-0.48), but at a lower significance level than either the tenderometer or shear methods.

INTRODUCTION

From the time man first tested his roast by spearpoint he has tried numerous methods for determining organoleptic qualities of meat. Taste, aroma, juiciness, tenderness and often appearance are involved in organoleptic evaluation. Extensive research has been conducted to correlate the physical, chemical and histological properties of meat to tenderness and other organoleptic factors. Because of individual differences in the subjective judging of tenderness, a continuing search for objective methods has been made to find a precise and reproducible method for gauging texture.

Most of the mechanical methods thus far developed have involved the measurement of the forces required to shear or penetrate a piece of meat of a certain cross section. Of these devices, the Warner-Bratzler shear apparatus has been the most widely used. For cooked samples, the Warner-Bratzler shear values correlate satisfactorily with organoleptic test values. As yet, no satisfactory method has been perfected which, by assay on raw meat, can predetermine tenderness in the cooked product. None of the various systems of grading cattle predicts with any certainty the tenderness of the processed meat. The need for a method to make such a prediction is evident.

The application of freeze-drying techniques to the preservation and storage of raw and cooked meats, with higher costs of processing and longer shelf life, make it doubly desirable that the quality of the end product be assured.

According to Sperring *et al.* (1) a satisfactory tenderometer should meet the following requirements: "(a) it should measure the tenderness of a small sample of raw or cooked meat, (b) it should give results quickly and be easy to operate, (c) it should give reasonably accurate results on a sample small enough for biopsy." In addition to these, we would add two more requirements: (d) the instrument should be portable, and (e) it should not be influenced by environmental factors, i.e., temperature, current drop, etc.

In recent years this Laboratory, in cooperation with the Feed Service Corporation of Crete, Nebraska, has studied the tenderness problem from the standpoint of developing an instrument which embodies the requirements set forth above. Preliminary data obtained with this instrument, the Morea Tenderometer, indicated that it could be used on raw beef to give good correlation with panel scores on cooked samples.

---

1. Sperring, D. D., Platt, W. T., and Hiner, R. L., *Food Technol.* 13, 155, 1959.

The ultimate purpose of this program was to find an objective method for measuring the texture of raw meat, with the view to predicting the tenderness in dehydrated steaks. To accomplish this goal, study of the Morea Tenderometer and various chemical constituents of Longissimus dorsi (ribeye) and Biceps femoris (round) muscles were made against the Warner-Bratzler shear test and an organoleptic panel, the acknowledged standards in the field.

EXPERIMENTAL

A. Materials and Methods

1. Carcasses Used

Beef samples were obtained from Mr. Kermit Larson of Oscar Mayer and Co., Madison, Wisconsin. Grading was done by a representative of the Meat Grading Branch, Livestock Division of the Agricultural Marketing Service. Carcasses representing Low U.S. Choice (A maturity), U.S. Good (B maturity), and U.S. Standard (C maturity) weighing approximately 575-600 pounds were selected.

Data obtained from the first set of samples indicated too great a similarity in texture between Choice and Good grades. In order to obtain a slightly greater gap in grade, Low Choice ribeyes were compared with U.S. Standard ribeyes rather than U.S. Good previously used. The last group of samples also included a section of the Biceps femoris muscle from the same carcass as the U.S. Choice ribeye. This muscle was not subjected to an organoleptic evaluation since the difference in texture would be too obvious.

Muscles tested were dissected from the carcass three days after slaughter and stored at 35°C until objective and subjective testing was done on the fourth day post mortem.

2. Subjective Tests

The whole L. dorsi muscles, from both the right and left sides of each animal were dissected and used in this program. The paired muscles from each carcass were cut in half (at approximately the sixth rib) and the anterior half of each was used for organoleptic evaluation. The posterior halves were used for objective measurements.

The organoleptic studies were conducted by the Wisconsin Alumni Research Foundation under the direction of Dr. J. Birdsall.

A complete description of cooking and panel procedures was given in the First Quarterly Report dated 15 March 1963 of this contract.

3. Objective Tests

The detailed procedures employed in the Warner-Bratzler shear, Morea Tenderometer, phosphate (ATP) and spectrographic technique for 18 elements were also described in the First Quarterly Report.

B. Results and Discussion

An attempt was made to select beef from production which would give relatively small but significant differences in texture. In the initial phase of the program comparisons were drawn between Low Choice and Good carcasses in order to hold as closely as possible to a narrow age range among the two groups of animals. Unfortunately, it was found that Choice and Good were not significantly different in textural characteristics in three out of four tests, and as a consequence it was necessary to widen the gap in grades to be tested.

When comparisons were made between Low Choice and Standard grade carcasses, a greater spread in data was seen for all procedures, but the differences were still not large. Although twelve Choice ribeyes were compared with an equal number of Standard ribeyes, the organoleptic panel scores were significantly different in only five tests. Since all 32 of the carcasses used in this study were picked at random, and were selected on the basis of hot weight, age and degree of marbling, it is remarkable that grade and tenderness were so poorly correlated. There is no doubt that current grading methods are deficient in this area of beef quality, since nearly all cuts of meat from the three grades used were of uniformly high quality.

Using the Warner-Bratzler shear and the organoleptic panel as base lines for tenderness, an attempt has been made to determine the following:

1. The ability of a new portable instrument, the Morea Tenderometer, to predict tenderness on raw meat, and

2. To determine the role of minerals in tenderness.

In principle, the Morea Tenderometer is an attempt to quantitate one of the first subjective measures of tenderness which an individual makes in eating beef; namely, the ease with which the meat is cut by a dull knife. In this instance a rotating dull knife is used to penetrate either raw or cooked beef and the data is recorded as a summation of cuts in a set number of revolutions. It is felt that the method is a summation measure of penetration, maximal extensibility and shear through muscle bundles and connective tissues.

The instrument is built in such a way that the depth of blade penetration per set number of revolutions may be read from either a kymograph tracing (area measurement expressed in square centimeters) or automatically with an electrometer integrating device. In the tests reported here, area measurements were used and therefore the data is transcribed in square centimeters.

Based on previous experience with this instrument, it was felt that the Morea Tenderometer would give a measurement on raw beef which would correlate well with panel scores, and also perhaps with the W-B shear.

Table 1 of the Appendix provides a statistical summary of the data amassed on 24 of the test samples (2C5 through 3C16). In this analysis of the data the organoleptic is represented by "y" and each of the other methods as an "x" function. The raw data from which this analysis was made is given in the Appendix, Tables 3-5.

The correlation coefficient (r) for the W-B shear method using cooked samples was found to be -0.66, significant at the 1% level. A similar r value has been reported by others (2, 3), so it is felt that the techniques used in the study are essentially sound.

The correlation coefficient for the Morea Tenderometer using raw meat was found to be +0.43, significant at the 5% level. This was not as high as was expected, but could probably be improved upon with a larger number of samples. The correlation coefficient of the Tenderometer when used on cooked meat was +0.57, significant at the 1% level, a value quite comparable to that of the W-B shear.

Correlation analysis was also run between the Warner-Bratzler shear for cooked meat and the Morea Tenderometer on raw meat. In this case a correlation coefficient of -0.54 was found which is significant at the 1% level.

In one group of seven carcasses (Samples 3C10-3C16, Table 3), *Biceps femoris* was obtained from the choice animals in addition to the *L. dorsi* muscles. The B. femoris was tested by shear and Tenderometer methods using both raw and cooked muscles. A comparison of the means was made in order to determine spread in the data and to determine the effect which cooking has on the values obtained by each method. The data given in Table 2 of the Appendix show the marked similarity of the methods in their response to cooking. The data do not show, however, that the shear test was unable to predict tenderness in two of the seven samples (Table 3, Samples 3C14, 3C15), while the Tenderometer did do so.

---

2. Doty, D. M., and Pierce, J. C.: Technical Bulletin #1231, Agricultural Marketing Service, U.S.D.A., July 1961.
3. Bratzler, L. J. and Smith, H. D.: *J. Food Sci.* *28*, 99, 1963.

Correlations involving specific minerals were run as shown in Table 1. Since time did not permit an analysis of each of the 18 elements listed in Table 5 of the Appendix, five elements were selected by inspection of the data and by their potential physiological function in the myofibril. Manganese, for example, was chosen for enzyme activator properties, as well as for its polyfunctionality (potential cross-linker). Iron was chosen to give an indication of a specific protein, myoglobin, as a determinant of tenderness. Zinc was selected because of its reported influence on muscle hydration (4), which in turn could bear on tenderness parameters. Magnesium-to-calcium ratios were determined and subjected to correlation analysis since both elements act as enzyme activators and antagonists. Physiologically, calcium is known to cause muscle tetany, while magnesium is involved in electronarcosis. Correlation coefficients for the elements are also given in Table 1, where it can be seen that only iron appears to relate to tenderness ($r=-0.48$), significant at the 5% level.

No attempt was made to correlate tenderness with either adenosine triphosphate or inorganic phosphate values which are given in Table 4 of the Appendix. It can be seen by inspection of the data that the individual values vary widely with no tendency to form a straight line pattern when plotted on graph paper. The same observation was made on plots of sodium, potassium, and potassium/magnesium/calcium ratios; no observable correlation was found to exist.

Although it is possible that certain of the elements listed in Table 5 could relate to tenderness, time did not permit an examination of those elements which would reflect the type of feed or geographic area from which the cattle were obtained.

On the basis of work now completed it is concluded that both the rotating knife tenderometer and the protein myoglobin (iron) merit further study in beef tenderness research.

---

4. Swift, C. E., and Berman, M. D.: Food Technol. 13, 365, 1959.

APPENDIX

TABLE 1

Linear Correlation Regression Coefficients Between Tenderness and Other Properties of Beef *Longissimus dorsi*

Statistic	Warner-Bratzler Cooked	Morea Tenderometer Raw	Morea Tenderometer Cooked	Mn	Fe	Zn	Mg/Ca Ratio
r	-0.66**	+0.43*	+0.57**	-0.28	-0.48*	-0.03	+0.29
b	-0.15	+0.08	+0.05	--	--	--	--
St. line	$\bar{y}$=7.53-0.15x	$\bar{y}$=1.95+.08x	$\bar{y}$=2.89+.05x	--	--	--	--
Syx	1.10	1.86	1.24	--	--	--	--
$t=\bar{d}/s_{\bar{d}}$ +	2.3*	3.10**	--	--	--	--	--
$\bar{d} \pm t_{.05} s_{\bar{d}}$	4.7±4.69	8.67±5.71	--	--	--	--	--

* significant at the 5% level
** significant at the 1% level
*** significant at the 0.1% level

\+ for the organoleptic data, $t=\bar{d}/s_{\bar{d}}$ = 5.15***

r for correlation coefficient

Syx for standard error of tenderness estimated from physical and chemical measurement

TABLE 2

A Comparison of Means for Warner-Bratzler Shear and Morea Tenderometer Using Raw and Cooked Beef *Longissimus dorsi* and *Biceps femoris*

Muscle	Warner-Bratzler* pounds		Morea Tenderometer* $cm.^2$	
	Raw	Cooked	Raw	Cooked
L. dorsi	14.2	18.7	41	29
B. femoris	28.4	22.1	18	25

* Average from seven carcasses tested. Both muscles were taken from the same animal.

TABLE 3

Test Data: Organoleptic and Physical Measurements

Beef Sample # C=U.S. Choice G=U.S. Good S=U.S. Standard	Organoleptic Mean average value per judge	Warner-Bratzler Raw (lbs. shear force)	Warner-Bratzler Cooked (lbs. shear force)	Tenderometer Raw (Integral area in cm.^{2})	Tenderometer Cooked (Integral area in cm.^{2})
1C1	5.02	13.8	20.1	53	--
1G1	5.21	11.4	13.0	61	--
1C2	4.17	12.1	19.0	60	--
1G2	2.76	9.3	18.1	60.0	--
1C3	3.86	17.7	19.8	39.0	--
1G3	4.85	15.5	15.1	46.0	--
1C4	4.44	13.3	12.3	52.0	--
1G4	5.08	16.9	16.9	33.0	--
2C5	6.4	17.6	12.0	40.0	38.0
2S5	3.9	23.2	15.0	39.0	44.0
2C6	4.7	17.3	10.7	42.	48
2S6	5.4	16.8	22.9	23	30
2C7	7.6	25.9	9.8	38	103
2S7	5.7	24.1	11.6	31	60
2C8	6.8	17.9	16.8	39	32
2S8	4.3	23.5	17.4	34	64
2C9	6.3	17.4	13.8	36	57
2S9	4.3	26.5	22.1	46	35
3C10	5.91	15.1	14.8	46	44
3S10	5.30	17.6	16.0	34	38
3C10-*B. femoris*		33.7	19.5	15	40
3C11	4.57	12.6	15.0	45	38
3S11	2.78	14.3	17.5	41	36
3C11-*B. femoris*		31.1	19.3	25	33
3C12	6.18	13.8	15.2	40	40
3S12	1.97	23.0	36.8	18	18
3C12-*B. femoris*		24.6	22.3	13	36
3C13	5.97	12.3	17.7	38	35
3S13	4.74	19.4	18.1	26	35
3C13-*B. femoris*		28.2	20.2	10	22
3C14	4.85	14.7	24.0	33	21
3S14	2.81	16.2	20.9	33	27
3C14-*B. femoris*		31.0	21.5	25	24
3C15	3.77	15.9	21.8	36	29
3S15	2.42	18.5	22.4	23	27
3C15-*B. femoris*		23.4	19.8	16	28
3C16	5.54	15.2	22.5	48	38
3S16	3.10	22.9	29.8	29	23
3C16-*B. femoris*		27.1	32.3	22	28

TABLE 4

Test Data: Proximate Analysis and Phosphate Determinations

Beef Sample # C=U.S. Choice G=U.S. Good S=U.S. Standard	Percent Moisture	Percent Nitrogen (dry wt.)	Percent Ash (dry wt.)	Inorganic Phosphate (as P in PPM wet weight)	ATP (as P in PPM wet wt.)	Total Phosphorus (PPM dry weight)
1C1	69.6	13.31		580	660	7,090
1G1	72.0	9.79		660	540	7,200
1C2	70.4	11.26	3.20	950	220	6,900
1G2	72.8	11.62	5.00	1,280	30	8,300
1C3	74.0	13.67	8.10	980	120	11,200
1G3	74.4	12.13	7.20	900	800	10,900
1C4	73.8	11.40	8.80	980	120	12,100
1G4	75.2	14.10	5.20	850	300	11,850
2C5	72.0	11.23	3.50	760	270	11,400
2S5	73.8	11.09	4.20	980	280	13,150
2C6	73.0	12.58	4.60	670	740	13,800
2S6	73.0	11.50	4.00	790	270	15,950
2C7	70.5	10.09	2.23	720	460	4,310
2S7	76.0	13.64	3.50	850	800	8,710
2C8	72.8	14.24	5.00	1,150	300	10,210
2S8	74.5	13.46	4.40	800	330	14,600
2C9	72.8	12.69	4.40	700	420	14,200
2S9	74.0	13.64	3.80	650	300	12,390
3C10	74.8	9.71	4.10			22,600
3S10	72.9	9.90	5.90			32,600
3C10-*B. femoris*	72.5	8.43	4.00			16,950
3C11	74.2	11.77	5.50			11,000
3S11	72.5		5.1			7,910
3C11-*B. femoris*	71.6	9.44	5.8			13,500
3C12	73.0	8.87	4.2			14,600
3S12	74.6		4.6			14,900
3C12-*B. femoris*	70.8	10.69	4.2			9,720
3C13	73.2	10.68	3.70			5,620
3S13	75.4	11.44	4.30			8,690
3C13-*B. femoris*	71.7	9.55	4.00			10,000
3C14	73.4	12.39	3.90			19,400
3S14	74.6	9.72	4.10			9,390
3C14-*B. femoris*	72.5					
3C15	73.8	12.88	3.40			11,950
3S15	72.9	14.01	4.30			17,900
3C15-*B. femoris*	75.0	14.98	3.60			12,205
3C16	70.5	12.91	4.33			6,810
3S16	72.5	13.03	4.13			8,680
3C16-*B. femoris*	71.7	9.86	4.58			11,400

TABLE 5

Test Data: Spectrographic Elemental Analysis (PPM Dry Weight)

Beef Sample # C=U.S. Choice G=U.S. Good S=U.S. Standard	B	Si	Al	Mn	Fe	Ca	Ni	Mo	Cu
1C1	<1.0	15.2	2.3	0.22	140	185	0.16	0.29	1.3
1G1	<1.0	12.3	2.2	0.10	107	128	< .10	0.16	1.2
1C2	0.34	<10.0	1.6	< .10	71	133	0.66	0.15	1.6
1G2	0.35	<10.0	2.1	0.21	123	197	0.54	0.17	2.0
1C3	0.36	10.0	4.0	0.24	164	262	0.11	0.17	2.0
1G3	0.37	9.8	3.7	0.14	90	154	0.19	0.20	1.4
1C4	0.83	16.8	34.5	0.41	234	284	0.88	0.42	<1.0
1G4	0.54	<10.0	2.4	0.20	122	215	0.18	0.30	1.1
2C5	>1.0	71.2	27.3	0.22	91.8	152	0.80	0.90	1.60
2S5	>1.0	9.0	9.8	0.13	71.0	151	0.22	0.37	1.10
2C6	>1.0	19.2	16.6	0.15	93.1	137	0.54	0.39	1.60
2S6	>1.0	13.4	12.7	0.13	95.2	196	0.62	0.33	1.60
2C7	>1.0	12.2	15.0	> .10	31.0	100	0.68	0.46	>1.0
2S7	>1.0	15.6	21.7	0.16	60.0	130	0.63	0.41	1.3
2C8	>1.0	10.0	14.3	0.19	99.0	119	0.68	0.57	1.1
2S8	>2.0	63.9	18.4	0.25	106	130	0.63	0.73	1.50
2C9	>1.0	37.8	68.2	0.28	157	144	1.0	0.55	1.70
2S9	>1.0	12.1	14.7	0.21	108	128	1.0	1.2	1.2
3C10	>1.0	29.0	14.6	0.19	108	84	0.25	0.37	1.6
3S10	>1.0	39.4	18.1	0.32	144	215	0.24	0.28	2.5
3C10-*B. femoris*	>1.0	18.4	9.4	0.16	95.1	216	> .1	0.15	1.1
3C11	>1.0	40.0	20.0	0.25	163	167	1.8	1.7	1.0
3S11	>1.0	25.5	21.0	0.36	98	155	0.84	1.1	1.3
3C11-*B. femoris*	>1.0	27.4	19.5	0.22	165	154	0.54	0.37	2.5
3C12	4.9	21.9	19.2	0.22	148	0.30	0.28	0.18	1.5
3S12	>1.0	18.6	20.6	0.26	330	208	0.72	0.83	1.7
3C12-*B. femoris*	>1.0	28.6	11.2	0.14	117	158	0.19	0.24	1.0
3C13	>1.0	16.4	2.3	0.14	60	120	0.67	0.50	1.1
3S13	>1.0	11.0	10.1	0.12	130	136	1.30	0.39	1.5
3C13-*B. femoris*	>1.0	24.0	15.4	0.35	149	209	0.36	0.58	1.5
3C14	>1.0	23.6	16.6	0.26	108	166	0.41	0.26	4.0
3S14	>1.0	16.4	18.2	0.19	81	145	0.42	0.33	1.1
3C14-*B. femoris*									
3C15	>1.0	38.6	14.0	0.13	113	126	0.24	0.40	1.1
3S15	>1.0	21.1	12.0	0.13	161	123	0.18	0.24	1.5
3C15-*B. femoris*	>1.0	21.6	13.0	0.14	126	140	0.17	0.24	1.5
3C16	>1.0	97.0	15.3	0.34	39.6	114	0.24	0.24	1.0
3S16	>1.0	19.0	11.4	0.97	121	122	0.12	0.22	1.3
3C16-*B. femoris*	>1.0	29.5	21.4	0.33	214	176	0.40	0.43	2.4

TABLE 5 (continued)

Test Data: Spectrographic Elemental Analysis (PPM Dry Weight)

Beef Sample # C=U.S. Choice G=U.S. Good S=U.S. Standard	Na	Mg	Zn	Co	K	Cr	Pb	V	Sn
1C1	3220	1100	107	0.22	13600	1.0	0.30	0.18	0.83
1G1	2210	950	108	0.19	9500	1.0	0.28	< .10	2.9
1C2	1710	635	84.0	0.21	7610	1.0	0.27	0.16	0.31
1G2	2640	1220	111	0.23	14400	2.1	0.31	0.33	1.0
1C3	4155	1395	144	0.20	19900	<1.0	0.35	< .10	1.5
1G3	2220	1120	112	0.26	14500	<10.0	0.71	0.30	1.0
1C4	4115	1850	105	0.67	22800	<1.0	1.2	1.2	3.8
1G4	3680	1420	85	0.31	19800	<1.0	0.48	0.33	0.58
2C5	2245	1125	118	1.0	6410	>1.0	0.56	0.60	0.56
2S5	2415	1145	95	0.24	5945	>1.0	0.33	0.22	0.37
2C6	1935	1020	106	0.41	5260	>1.0	0.59	0.35	0.71
2S6	3220	1365	147	0.37	10610	>1.0	0.46	0.56	0.82
2C7	980	670	40	0.72	2905	1.7	> .10	> .10	0.41
2S7	1370	901	98	0.61	4915	1.9	> .10	> .10	0.41
2C8	1410	905	98	0.81	4115	> .10	> .10	0.80	1.60
2S8	2610	1210	124	1.3	7200	> .10	> .10	0.96	3.10
2C9	3360	1440	208	1.5	10610	4.5	> .10=	1.5	2.10
2S9	2110	1115	224	2.6	5760	> .1	> .1	1.4	1.20
3C10	1835	665	258	0.29	7600	> .1	> .1	> .1	0.43
3S10	2720	1390	227	0.28	9920	> .1	> .1	> .1	0.79
3C10-*B. femoris*	1718	440	82.2	0.16	6080	> .1	> .1	> .1	0.61
3C11	1675	629	164	0.52	9600	>1.0	1.8	>1.0	3.8
3S11	1860	520	121	0.39	8900	> .10	> .10	> .10	1.0
3C11-*B. femoris*	1600	630	137	0.85	8100	> .10	0.71	> .10	0.78
3C12	2890	555	143	0.39	16000	> .10	> .1	> .10	0.55
3S12	2160	850	205	1.2	13600	> .10	> .10	> .10	1.2
3C12-*B. femoris*	1380	440	106	0.45	5460	> .10	> .10	> .10	0.70
3C13	1080	315	68	1.00	2700	> .10	2.4	> .10	>1.0
3S13	1800	515	109	0.93	7410	> .10	4.2	> .10	> .10
3C13-*B. femoris*	2150	651	72	0.47	7800	> .10	4.9	> .10	> .10
3C14	1915	1206	114	.47	10900	> .10	> .10	> .10	0.79
3S14	1640	965	96	.68	8400	> .10	> .10	> .10	1.4
3C14-*B. femoris*									
3C15	2005	905	90	.34	7775	> .10	> .10	> .10	1.8
3S15	1810	960	85	.32	8110	> .10	> .10	> .10	3.4
3C15-*B. femoris*	1975	651	89	.41	7100	> .10	> .10	> .10	.37
3C16	910	293	47.6	.25	3600	> .10	0.55	> .10	1.1
3S16	1235	392	72	.20	4200	> .10	> .10	> .10	15.6
3C16-*B. femoris*	1598	680	70	.40	6280	> .10	> .10	> .10	1.2

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) BJORKSTEN LABORATORIES, INC. Madison, Wisconsin	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
A COMPARISON OF TENDERNESS PARAMETERS IN DEHYDRATED MEAT

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final. September 1962 - September 1963

5. AUTHOR(S) (Last name, first name, initial)
ANDREWS, FRED A.
UNDERWOOD, CHESTER E.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1965	12	4

8a. CONTRACT OR GRANT NO. DA19-129-AMC-2102(N) b. PROJECT NO. 7X86-06-033 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) FD-25

10. AVAILABILITY/LIMITATION NOTICES
Qualified requestors may obtain copies of this report from DDC. Release to Clearing House for Federal Scientific and Technical Information is authorized.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Food Division, U. S. Army Natick Laboratories, Natick, Mass. 01762.

13. ABSTRACT

Longissimus dorsi muscles from 32 beef carcasses were analyzed for tenderness using the Warner-Bratzler shear test, a new rotating knife tenderometer, and an organoleptic panel. In addition, 18 mineral, adenosine triphosphate, and proximate analyses were made.

The rotating knife tenderometer and the Warner-Bratzler shear test were found to correlate well with the sensory panel ($r = +0.57, -0.66$).

Iron content of the tissues was also found to correlate with the sensory panel ($r = -0.48$), but at a lower significant level than either the tenderometer or shear methods.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C		LINK D	
	ROLE	WT	ROLE	WT	ROLE	WT	ROLE	WT
Measurement	8				8			
Texture	9				9			
Meat	9				9		7	
Raw	0				0			
Prediction			8					
Parameters			8					
Tenderness			9		9		7	
Beef			9				7	
Dehydrated			0					
Correlation					8			
Warner-Bratzler shear					10			
Morea tenderometer	10				10			
Taste tests					10			
Cooked					0			
Minerals							6	
Iron							6	

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ______________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ______________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ______________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.